Tropical Meteorology – Homework #3

Due Date: 15 March 2018

Learning Objectives: In this assignment, you will *apply* your understanding of the Madden-Julian Oscillation and Hovmöller analysis developed in previous lectures and assignments to *generate* understanding about Madden-Julian Oscillation (a) seasonal to annual variation and (b) influences on weather patterns across the United States.

1. For this question, please use the Hovmöller plots available on the course website at http://derecho.math.uwm.edu/classes/TropMet/assignments/HW-EW/. There are a total of twenty-nine images in this directory, encompassing the period from 1 April 2011 to 21 January 2018. Images are numbered sequentially in time. All images are courtesy Carl Schreck's webpage at https://ncics.org/portfolio/monitor/mjo/.

   On these images, outgoing longwave radiation anomalies averaged between 7.5°S and 7.5°N (until July 2015; 5°S to 5°N thereafter) are shaded per the color bar at the bottom of each image. Negative (positive) values indicate greater (lesser) thunderstorm activity. Blue (black after July 2015) contours denote outgoing longwave radiation anomalies associated with the Madden-Julian Oscillation (MJO). Enhanced (suppressed) thunderstorm activity is denoted by solid (dashed) contours; where concentric contours exist, thunderstorms are particularly enhanced or suppressed.

   a. (5 pts) Over what range of longitudes are the convectively enhanced and convectively suppressed phases of the MJO most commonly found?

   b. (5 pts) During what times of the year is the MJO most and least active?

   c. In a review of the synoptic- to sub-seasonal effects of the Madden-Julian Oscillation, Zhang (2013, *Bull. Amer. Meteor. Soc.*) states that "[recent] major ENSO warming events (El Niño) were preceded by extraordinarily strong episodes of the MJO."

      i. (15 pts) Based upon what you know about the structure of the MJO and how El Niño events form, discuss why this statement may be true.

      ii. (15 pts) The first ten months of 2015 featured the development of a strong El Niño event. To what extent is the statement above supported by the Hovmöller plots? Describe.

      iii. (15 pts) Just as the MJO may influence ENSO, it is believed that ENSO may influence the MJO. Consider the periods 1 July 2011-31 January 2012 (La Niña) and 1 March 2015-11 February 2016 (El Niño). Describe differences in the MJO (occurrence, intensity, and eastward

extent, if such differences are evident) between these periods. Hypothesize why these differences exist.

2. Rossby wave trains emanating from areas of enhanced convection associated with the MJO can exert an influence upon mid-latitude weather. The Climate Prediction Center's website contains plots of three-month-averaged surface temperature anomalies over the continental United States for each MJO phase. Each figure contains sixteen panels. In the leftmost eight panels, the surface temperature anomalies (°C) for each MJO phase are plotted. In the rightmost eight panels, statistical significance of the surface temperature anomalies for each MJO phase is plotted, with medium-blue to purple shading indicating statistically significant temperature anomalies to $\geq 90\%$ confidence.

    a. (5 pts) Click on "JFM," for January, February, and March. Consider the western Great Lakes and Upper Midwest. Which MJO phases have statistically significant cold anomalies? Which have statistically significant warm anomalies?

    b. (10 pts) The Bureau of Meteorology maintains archived MJO phase space data. In these data, the first three columns indicate the year, month, and date, respectively. The fourth and fifth columns denote the daily value of RMM1 and RMM2 from the Wheeler and Hendon (2004) MJO phase space. Save the data for 11-23 February 2017 into a text file. Create a line scatterplot of RMM1 (*x*-axis, -4 to +4) versus RMM2 (*y*-axis, -4 to +4) using your favorite plotting software. Please label each axis. Indicate which ends of your line correspond to 11 and 23 February.

    c. (10 pts) The NCEP/NCAR Reanalysis plotted from NOAA/ESRL/PSD can be used to obtain daily mean composites of a wide range of atmospheric fields. Use this tool to obtain a plot of *anomalous surface temperature* for the period 11-23 February 2017 over the United States, including state borders.

    d. (10 pts) Using your result to (b), compare your plot from (c) to that from (a). Does evidence exist to support the hypothesis that the observed surface temperature anomalies for 11-23 February 2017 resulted in whole or in part from the MJO? Why?

    e. (10 pts) Repeat (a) for DJF and (b) and (c) for 25 December 2017-6 January 2018. Include each plot from (b) and (c) with your completed assignment. Does evidence exist to support the hypothesis that the observed surface temperature anomalies for 25 December 2017-6 January 2018 can be connected to the MJO? Why?